

WHAT IS CLAIMED IS:

1           1.       A method for depositing a dielectric film on a substrate in a process  
2 chamber, the method comprising:

3               (a)     providing a first gaseous mixture to the process chamber, the first  
4 gaseous mixture comprising a first deposition gas and a first inert gas source;

5               (b)     generating a first high-density plasma from the first gaseous  
6 mixture to deposit a first portion of the film on the substrate with a first deposition/sputter  
7 ratio within the range of 5 – 20, wherein the first deposition/sputter ratio is defined as a  
8 ratio of a sum of a first net deposition rate and a first blanket sputtering rate to the first  
9 blanket sputtering rate;

10              (c)     thereafter, cooling the substrate;

11              (d)     thereafter, flowing an etchant gas into the process chamber;

12              (e)     thereafter, providing a second gaseous mixture to the process  
13 chamber, the second gaseous mixture comprising a second deposition gas and a second  
14 inert gas source; and

15              (f)     generating a second high-density plasma from the second gaseous  
16 mixture to deposit a second portion of the film on the substrate.

1           2.       The method according to claim 1 wherein the second gaseous  
2 mixture is substantially the same as the first gaseous mixture.

1           3.       The method according to claim 1 wherein the deposition/sputter  
2 ratio is in the range of 9 – 15.

1           4.       The method according to claim 1 wherein the step of generating a  
2 second high-density plasma is performed with a second deposition/sputter ratio within the  
3 range of 5 – 20, wherein the second deposition/sputter ratio is defined as a ratio of a sum  
4 of a second net deposition rate and a second blanket sputtering rate to the second blanket  
5 sputtering rate.

1           5.       The method according to claim 4 wherein the second  
2 deposition/sputter ratio is less than the first deposition/sputter ratio.

1           6.       The method according to claim 1 wherein the etchant gas  
2 comprises remotely dissociated etchant atoms.

1 7. The method according to claim 6 wherein the remotely dissociated  
2 etchant atoms comprise fluorine atoms.

1 8. The method according to claim 7 wherein the fluorine atoms are  
2 provided by  $\text{NF}_3$ .

1 9. The method according to claim 1 further comprising the step of  
2 dissociating the etchant gas into dissociated etchant atoms within the process chamber.

1 10. The method according to claim 9 wherein the etchant gas is a  
2 fluorine-containing gas.

1 11. The method according to claim 9 wherein the etchant gas is  $\text{NF}_3$ .

1 12. The method according to claim 1 wherein the dielectric film is a  
2 silicon oxide film.

1 13. The method according to claim 1 wherein the dielectric film is a  
2 fluorinated silicon oxide film.

1 14. The method according to claim 1 wherein the dielectric film is  
2 deposited over a plurality of stepped surfaces formed on the substrate having gaps formed  
3 between adjacent ones of the stepped surfaces and wherein the first portion of the film  
4 partially fills the gaps.

1 15. The method according to claim 14 wherein the second portion of  
2 the film completes filling the gaps.

1 16. The method according to claim 1 wherein the step of cooling the  
2 substrate is performed external to the process chamber.

1 17. A computer-readable storage medium having a computer-readable  
2 program embodied therein for directing operation of a substrate processing system  
3 including a process chamber; a plasma generation system; a substrate holder; and a gas  
4 delivery system configured to introduce gases into the process chamber, the computer-  
5 readable program including instructions for operating the substrate processing system to

6 deposit a dielectric film on a substrate disposed in the process chamber in accordance  
7 with the following:

- 8 (a) providing a first gaseous mixture to the process chamber, the first  
9 gaseous mixture comprising a first deposition gas and a first inert gas source;
- 10 (b) generating a first high-density plasma from the first gaseous  
11 mixture to deposit a first portion of the film on the substrate with a first deposition/sputter  
12 ratio within the range of 5 - 12, wherein the first deposition/sputter ratio is defined as a  
13 ratio of a sum of a first net deposition rate and a first blanket sputtering rate to the first  
14 blanket sputtering rate;
- 15 (c) thereafter, cooling the substrate;
- 16 (d) thereafter, flowing an etchant gas into the process chamber;
- 17 (e) thereafter, providing a second gaseous mixture to the process  
18 chamber, the second gaseous mixture comprising a second deposition gas and a second  
19 inert gas source; and
- 20 (f) generating a second high-density plasma from the second gaseous  
21 mixture to deposit a second portion of the film on the substrate.

1 18. The computer readable storage medium according to claim 17  
2 wherein the second high-density plasma is generated to deposit the second portion of the  
3 film with a second deposition/sputter ratio within the range of 5 - 20, wherein the second  
4 deposition/sputter ratio is defined as a ratio of a sum of a second net deposition rate and a  
5 second blanket sputtering rate to the second blanket sputtering rate.

1 19. The computer-readable storage medium according to claim 17  
2 wherein the dielectric film is to be deposited over a plurality of stepped surfaces formed  
3 on the substrate having gaps formed between adjacent ones of the stepped surfaces and  
4 wherein the first portion of the film partially fills the gaps.

1 20. A substrate processing system comprising:  
2 (a) a housing defining a process chamber;  
3 (b) a high-density plasma generating system operatively coupled to the  
4 process chamber;  
5 (c) a substrate holder configured to hold a substrate during substrate  
6 processing;

7 (d) a gas-delivery system configured to introduce gases into the  
8 process chamber;  
9 (e) a pressure-control system for maintaining a selected pressure  
10 within the process chamber;  
11 (f) a controller for controlling the high-density plasma generating  
12 system, the gas-delivery system, and the pressure-control system; and  
13 (g) a memory coupled to the controller, the memory comprising a  
14 computer-readable medium having a computer-readable program embodied therein for  
15 directing operation of the substrate processing system, the computer-readable program  
16 including  
17 (i) instructions to control the gas-delivery system to provide a  
18 first gaseous mixture to the process chamber, the first gaseous mixture comprising a first  
19 deposition gas and a first inert gas source;  
20 (ii) instructions to control the high-density plasma generating  
21 system to generate a first high-density plasma from the first gaseous mixture to deposit a  
22 first portion of the film on the substrate with a first deposition/sputter ratio within the  
23 range of 5 – 20, wherein the first deposition/sputter ratio is defined as a ratio of a sum of a  
24 first net deposition rate and a first blanket sputtering rate to the first blanket sputtering  
25 rate;  
26 (iii) instructions to control the gas-delivery system thereafter to  
27 flow a heat-transfer gas to cool the substrate;  
28 (iv) instructions to control the gas-delivery system thereafter to  
29 flow an etchant gas into the process chamber;  
30 (v) instructions to control the gas-delivery system thereafter to  
31 provide a second gaseous mixture to the process chamber, the second gaseous mixture  
32 comprising a second deposition gas and a second inert gas source; and  
33 (vi) instructions to control the high-density plasma generating  
34 system to generate a second high-density plasma from the second gaseous mixture to  
35 deposit a second portion of the film on the substrate.

1 21. The substrate processing system according to claim 20 wherein the  
2 instruction to generate a second high-density plasma comprise instructions to deposit the  
3 second portion of the film with a second deposition/sputter ratio within the range of 5 –  
4 20, wherein the second deposition/sputter ratio is defined as a ratio of a sum of a second

5 net deposition rate and a second blanket sputtering rate to the second blanket sputtering  
6 rate.

1                    22.     The substrate processing system according to claim 20 wherein the  
2     dielectric film is to be deposited over a plurality of stepped surfaces formed on the  
3     substrate having gaps formed between adjacent ones of the stepped surfaces and wherein  
4     the first portion of the film partially fills the gaps.

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